UNIVERSITI PUTRA MALAYSIA

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN WATERSHED RUNOFF ANALYSIS: CASE STUDY OF SUNGAI PANGSUN WATERSHED, ULU LANGAT, SELANGOR

TAN TECK HOCK

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By

TAN TECK HOCK

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN WATERSHED RUNOFF ANALYSIS: CASE STUDY OF SUNGAI PANGSUN WATERSHED, ULU LANGAT, SELANGOR

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Chairman : Associate Professor Dr. Lai Food See

Faculty : Forestry

This study aims at developing a GIS aided analysis to generate watershed runoff data. For this purpose, the Sg. Pangsun watershed, a small headwater catchment located in Ulu Langat, Selangor was chosen as an experimental ground. This basin has an area of approximately 2.6 km^2 and lies on the southern flank of the Main Range.

Two GIS-based software namely ARC/INFO 3.4 and ArcView 3.1 with Spatial Analyst 1.1a, 3D-Analyst and the Hydrology extensions were applied in this study. The former was employed to create three digital coverages of geographical features, namely, stream, contour and boundary from topographic maps to be used as database by the latter to perform spatial and hydrological analyses which generated

three intended themes, namely, grid slope, flow accumulation and stream network. The grid slope theme provided slope values for the calculation of overland and channel flows travel times on cells concerned using continuity-momentum and Manning-continuity principles respectively. The flow accumulation theme on the other hand delineated the main channel of the study watershed whose water on its cells considered as channel flow. The stream network theme provided the flow path of runoff (distance) for computation of the various time units taken by runoff from cells of both overland and channels flows to travel to the watershed outlet. The cells (partial watershed areas) were then categorized based on their travel times to produce the time-area histogram that represents the translation effect of runoff (equilibrium flow) on watershed surface. Clark's Instantaneous Unit Hydrograph method was later used to take into account the storage effect of the study watershed (delay caused by surface detention, saturation of soil profile, etc.) to produce a 15-minute unit hydrograph (UH).

The derived 15-minute UH compares reasonably well with the mean observed UH of similar duration in terms of peak, concentration time, W50 and W75 with slight variances of 0.162 m^3/s, 15, 5.8 and 7.7 minutes respectively. However, the average time base, W0, is about 315 minutes longer. By changing the Manning coefficient to 0.011 which represents bare soil, the peak flow and concentration time of 15-min UH were found to be 27.3 % higher and shorter 150 % respectively. The UH derived was subsequently used to generate runoff hydrographs for May 1997 to April 1998. The recession limbs of some generated runoff

hydrographs were found to be underestimated when compared to observed counterparts despite adjustments being done using Barnes' equation. This is probably due to the influence of interflow and groundwater which was difficult to ascertain since no field observations were made during the period of study. As a result of this, the accuracy of monthly total runoffs, runoff coefficients and peak discharges calculated from them was affected. Finally, it is suggested that a more accurate technique of determining baseflow, perhaps supported with field experiment, in compiling runoff hydrograph should alleviate this shortcoming.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGGUNAAAN SISTEM MAKLUMAT GEOGRAFI (GIS) UNTUK MENGANALISA ALIRAN PERMUKAAN KAWASAN LEGEH: SATU KES KAJIAN DI KAWASAN LEGEH SG. PANGSUN, ULU LANGAT, SELANGOR

Oleh

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Pengerusi : Profesor Madya Dr. Lai Food See

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Kajian ini bertujuan untuk membina satu analisis GIS yang menjana data aliran permukaan kawasan legeh. Bagi tujuan ini, kawasan legeh Sg. Pangsun, Ulu Langat, Selangor telah dipilih sebagai tempat kajian. Kawasan legeh ini mempunyai keluasan lebih kurang 2.6 km^2 dan terletak di kawasan pergunungan yang curam di bahagian selatan Banjaran Utama.

Dua jenis perisian GIS telah digunakan dalam kajian ini iaitu ARC/INFO 3.4 dan ArcView 3.1 dengan sambungan Spatial Analyst 1.1a, 3D-Analyst dan Hydrology. ARC/INFO 3.4 telah digunakan untuk membina tiga lapisan digital yang berciri geografi iaitu sungai, garisan kontur and sempadan daripada peta topografi. Ketiga-tiga lapisan digital ini kemudian dijadikan sebagai pangkalan data bagi analisis di ArcView demi menjana tiga theme iaitu petak kecerunan, tumpuan aliran dan

rangkaian aliran. Theme petak kecerunan membekalkan nilai kecerunan bagi pengiraan masa pengaliran aliran permukaan dan saluran pada petak-petak yang berkaitan berdasarkan prinsip continuity-momentum dan Manning-continuity masing-masing. Sebaliknya, theme tumpuan aliran menjanakan saluran utama kawasan kajian dimana air pada petak-petak dianggap sebagai aliran saluran. Theme rangkaian aliran manakala memberi laluan aliran permukaan (jarak) bagi pengiraan masa yang diambil oleh aliran permukaan pada petak-petak untuk sampai ke hilir. Petak-petak yang mewakili permukaan tanah dan sungai kawasan kajian seterusnya dikategorikan berdasarkan masa aliran untuk membina histogram masa-keluasan yang mewakili kesan permindahan aliran permukaan. Kaedah Clark's Instantaneous Unit hydrograph seterusnya digunakan mengambil kira kesan takungan kawasan legeh bagi menghasilkan 15-minit unit hidrograf (UH).

15-minit UH yang terbentuk didapati berbanding baik dengan min UH daripada data sebenar dari segi puncak, masa tumpuan, W50 dan W75 dengan hanya menunjukkan sedikit variasi iaitu 0.162 m^3/s, 15, 5.8 dan 7.7 minit masing-masing. Walau bagaimanapun, masa dasar iaitu W0 adalah terlebih anggap sebanyak 315 minit. Dengan menukarkan Manning kepada 0.011 yang mewakili tanah tandus, puncak and masa tumpuan 15-minit UH menjadi 27.3 % lebih tinggi and singkat sebanyak 150%. UH yang diperoleh seterusnya digunakan untuk membina hidrograf aliran permukaan bagi Mei 1997 sehingga April 1998. Lengkungan menurun sesetengah hidrograf aliran permukaan yang diperoleh adalah didapati kurang anggar berbanding dengan hidrograf sebenar walaupun penyelarasan telah dibuat

dengan menggunakan persamaan Barnes. Ini mungkin disebabkan oleh pengaruh daripada aliran pertengahan and bawah tanah yang sukar ditentukan memandangkan tiada kajian dilakukan ke atas ini ketika projek ini dijalankan. Oleh itu, adalah dicadangkan bahawa teknik yang lebih jitu dengan sokongan experimen di lapangan digunakan untuk menentu aliran dasar bagi menghasilkan hidrograf aliran permukaan supaya kelemahan ini dapat diatasi.

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I certify that an Examination Committee met on 20th May 2002 to conduct the final examination of Tan Teck Hock on his Master thesis entitled "Application of Geographic Information System (GIS) in Watershed Runoff Analysis: Case Study of Sungai Pangsun Watershed, Ulu Langat, Selangor" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committees are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(TAN TECK HOCK)

Date: 20 May 2002

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3D	3 dimension
AAT	Arc Attribute Table
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
ID	Identifier
IUH	Instantaneous unit hydrograph
n	Manning's n value
K_r	constant of recession
K_s	Constant of storage effects
PAT	Polygon/Point Attribute Table
RE	Reynolds number
Sg.	Sungai/river
TIN	Triangular irregular network
UH	Unit hydrograph

CHAPTER ONE

INTRODUCTION

1.0 General

Runoff data is important in water resource engineering designs. Information regarding runoff characteristics such as total discharge and peak flow is needed in the planing and designing of water related projects like storage tanks and dams for hydroelectric, irrigation or water supply to generate intended supplies and in some instances, contain potential damages resulting from floods. Such data is also very much required in the construction of infrastructures like detention ponds and drainage systems for flood mitigation purposes. In Malaysia where the number of aforementioned water related projects is growing because of population growth, urbanization, expansion of agriculture, logging activities, and industrialization, runoff data is consistently sought after.

Acquisition of runoff data involves installation of water level recorders usually used to compute streamflow in the field. A current meter is sometimes used to measure the stream velocity. As procurement of runoff data from field is used to be laborious, costly and time-consuming as well as the increase understanding in factors affecting formation of runoff, hydrologists or engineers therefore have